NEW SCENARIOS SHAPING A DIGITAL TWIN EARTH FOR SECURITY

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ABSTRACT

The security domain cannot longer be considered as a standalone silo. To properly understand the complex current security scenarios, it is necessary to have a holistic approach and investigate the links of security with different domains (e.g. climate, hazards, health, energy, food). A new security paradigm is emerging and new data, technologies and models are needed to comprehend recent complex dynamics. The goal is being able to reproduce interconnected scenarios through a digital replica of the Earth, with a specific focus on security.

Index Terms— *New Security, Climate Security, Digital Twin Earth*

1. INTRODUCTION

Security is an intricate subject in which a diverse number of scenarios can be triggered by causes of different nature. The links between events affecting security and other domains (e.g. climate, hazards, health, energy, food) are highlighted in the most relevant global policies (e.g. Sustainable Development Agenda, Sendai Framework, Paris Agreement, EU Green Deal) as well as in the work programmes of key entities such as the Group on Earth Observations (GEO). Thus, the change from the traditional paradigm of security as isolated domain (where ad-hoc analyses are performed on specific areas of interest) to a broader new concept of security is ongoing. One of the most relevant examples of this new security paradigm is the so called Climate Security, which refers to how climate change related events amplify existing risks in society, endangering the safety of citizens, key infrastructures, economies or ecosystems.

Fortunately, technology is also evolving in a good pace and, in particular, that related to observations of the Earth from space and associated data processing solutions. The adoption of state-of-the-art IT technologies (e.g. High-Performance Computing, Big Data, Artificial Intelligence), together with the current wealth of data, tailored to the Earth Observation (EO) domain, can help to not only understand what is happening in the world and its likely causes, but also to predict and anticipate potential threats. These current advances in technology make it possible to start conceiving an innovative and accurate digital replica of the Earth, also incorporating foresight capabilities, called Digital Twin Earth (DTE).

The European Union Satellite Centre (SatCen), through its Research, Technology Development and Innovation (RTDI) Unit, is working in an advanced DTE concept in which new complex security scenarios can be monitored and analysed by means of a deep understanding of the global aspects of our planet having an impact on the safety and security of citizens and societies. The present work describes several new security scenarios and how they are serving to build a Digital Twin Earth for Security exploiting state-of-the-art solutions in data usage, technology and modelling.

2. A DIGITAL TWIN EARTH FOR SECURITY

The Digital Twins concept has been around for decades. Recently it has received increased attention, demonstrated through the initiative launched by the European Commission, DestinE [1], with preparatory activities complemented by contributions from relevant institutions like the European Space Agency (which is already assessing how EO can support building the Digital Twin Earth). The DTE, which can be considered a virtual copy or interactive model of the Earth facilitating the monitoring and understanding of the planet itself and offering prediction capabilities, is built on three main pillars: data, technology and models. These pillars are deeply interconnected: models need data, and both data and models require the use of latest technologies to generate valuable information and results.

SatCen, through its RTDI Unit, and building on its Geospatial Data Management Platform (GEO-DAMP) [2], is working on a first prototype of a DTE for Security [3]. GEO-DAMP is an advanced environment where EO users and developers can interact for continuously enhancing capabilities to work in EO applications relevant for security, enabling them to cope with the growing demand throughout the different phases of the data value chain (e.g. discovery, access, processing and exploitation of EO and collateral data). GEO-DAMP is also exploring relevant connections with other systems belonging to different domains (e.g. climate), in order to properly link the security aspect to interconnected domains.

3. NEW SECURITY SCENARIOS

This section describes different examples of new security scenarios addressed by SatCen, their implementation in the GEO-DAMP environment and how they could be of interest while building a DTE for Security.

3.1 Conflict Pre-Warning (CPW) Map

Climate related events are having an impact on population displacement and conflicts. A prototype dashboard of the GEO-DAMP suite has been generated within the H2020 GEM[1] project where several data (e.g. ACLED[2] conflict database, meteorological data, statistical data on demographics, socio-economic variables, displacement data, EO data) can be accessed to provide an overview of a specific Area of Interest (Figure 1). The application of Machine Learning techniques is being developed to look into the causal relations between the observed variables [4] with regards to specific events (e.g. identify those climate variables most likely affecting migration and/or conflicts in a given scenario). Processing models for EO data (e.g. water level extraction, flood detection) are also included to create advanced products from EO data analysis.

3.2 Flood Risk & Impact Assessment Tool

Flood events are increasing worldwide, having an impact on the safety of citizens and related activities. A relevant pilot is currently under development in the frame of the H2020 E-SHAPE[3] project to implement services based on Sentinel-1 / -2 data and other ancillary data (e.g. climate and statistical data). The FRIEND (Flood Risk & Impact assEssment through automatic chaNge Detection of S-1+S-2 images) service will be built on the SatCen experience of the Char Piya study [5] and the OGC Disaster pilot 2021. Data access and processing pipelines will be based on internal SatCen infrastructures as GEO-DAMP and DIASes as CREODIAS. Processing pipelines on Sentinel-1 and Sentinel-2 data will generate time-series and automatically detect changes above specific Areas of Interest. The output will provide both citizens and experts with a Flood Risk & Impact Assessment Tool based on indicators, time-series charts and forecast maps (Figure 2).

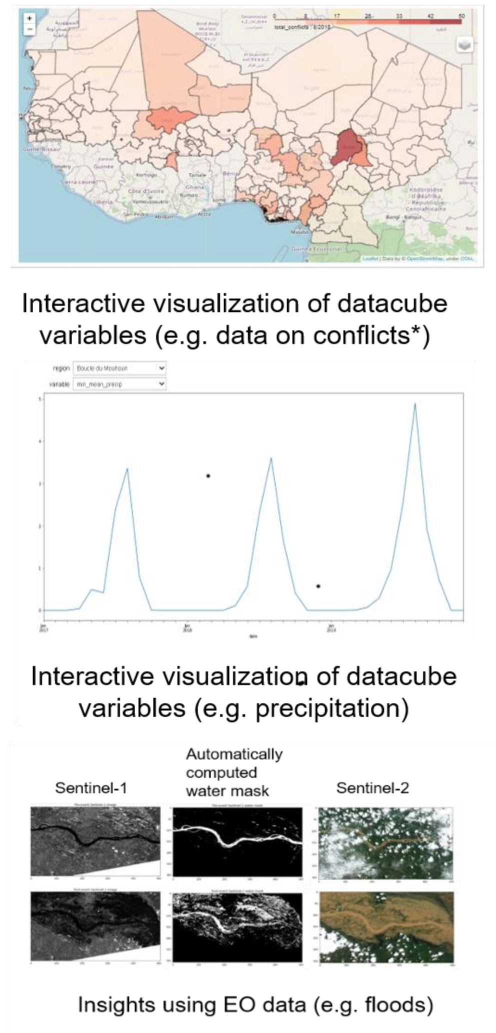

Figure 1: CPW dashboard and capabilities

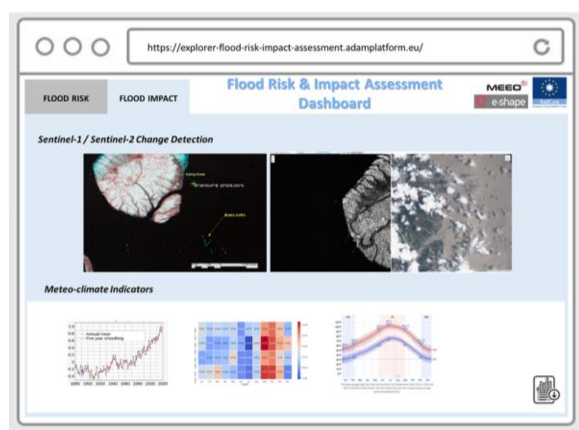

Figure 2: Flood Risk mock-up interface

[1] www.globalearthmonitor.eu
[2] www.acleddata.com
[3] https://e-shape.eu

3.3 Underground water extraction and security issues

The increasing scarcity of fresh water can lead to politician instability and affect the safety and security of population (e.g. leading to water access provision, crop yield reduction, conflict and migration). A pilot is currently under development at SatCen to address the vulnerability of a pre-identified region, based on Sentinel-1 data. The creation of interferometric products within GEO-DAMP will help users to detect underground water extraction. The output will consist in maps describing the vulnerability of such areas and the risks for population and infrastructures as well as the consequences related to water and food security.

3.4 Oil tanks resources and pandemics

The recent Covid-19 pandemic showed the vulnerability of energy resources when the regional lockdowns in multiple countries had a big impact on the oil inventories.

In a testing pilot implemented at SatCen, a new methodology to monitor oil inventories using Sentinel-1 data was developed. A specific pre-processing of SLC Sentinel-1 images was designed to highlight the difference in the backscatter responses with respect to the roof level in floating roof tanks [6]. Taking advantage of the technologies offered by GEO-DAMP for discovery, access, processing and analysis, the output provided the classification of oil tanks and the prediction of stock during one year over Cushing, Oklahoma (a major trading hub for crude oil) (Figure 3).

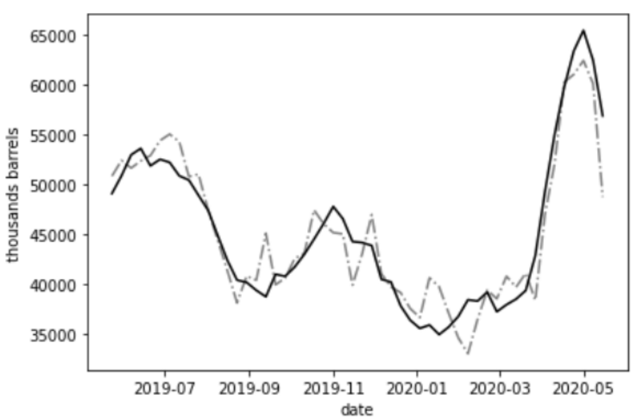

Figure 3: Predicted stock (grey) vs ground truth from the US EIA (black)

3.5 Illegal mining and environmental effects

Illegal activities could have a direct consequence to environment and climate. The Madre de Dios region in Peru has been for years affected by illegal deforestation and mining activities, causing the pollution of water resources and biomass variation. Cloud computing resources were exploited to process Big Geospatial Data from Sentinel-1 and -2 through suitable EO pipelines (e.g. thematic indexes - Figure 4 - and change detection algorithms) and investigate environmental effects of illegal activities (e.g. illegal mining). These pipelines, available in GEO-DAMP, were initially developed within the H2020 project BETTER[4], concluded in early 2021.

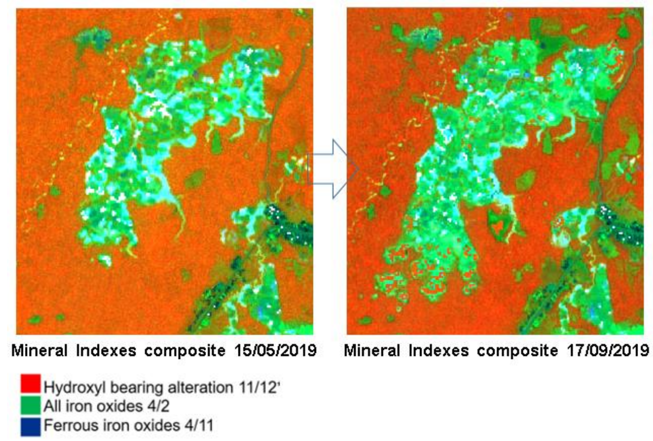

Figure 4: Example of mineral indexes generated with Sentinel-2 to monitor illegal mining

4. CONCLUSIONS

The present works aims to demonstrate how the security domain has to be seen as a complex framework where different domains are interconnected (e.g. climate, hazards, health, energy, food). Several scenarios tackled by SatCen are presented. These scenarios are related to climate security, disasters and citizen security, energy security and illegal activities impacting on environment. A number of pilots have been implemented through different R&I initiatives and integrated into the SatCen GEO-DAMP suite of services. These scenarios showcase how, through a precursor of a DTE for security, heterogeneous data, analyzed through different models with the support of advanced technologies, lead to decision ready information, actionable by decision makers. GEO-DAMP served therefore as fesibility demonstrator of a flexible and extensible system where data, technologies and models are interconnected. These three pillars constitute the basis for a Digital Twin Earth for Security. While extending the capabilities of a DTE for Security, interconnection with other DTEs can be pursued.

[4] www.ec-better.eu

5. ACKNOWLEDGEMENTS

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